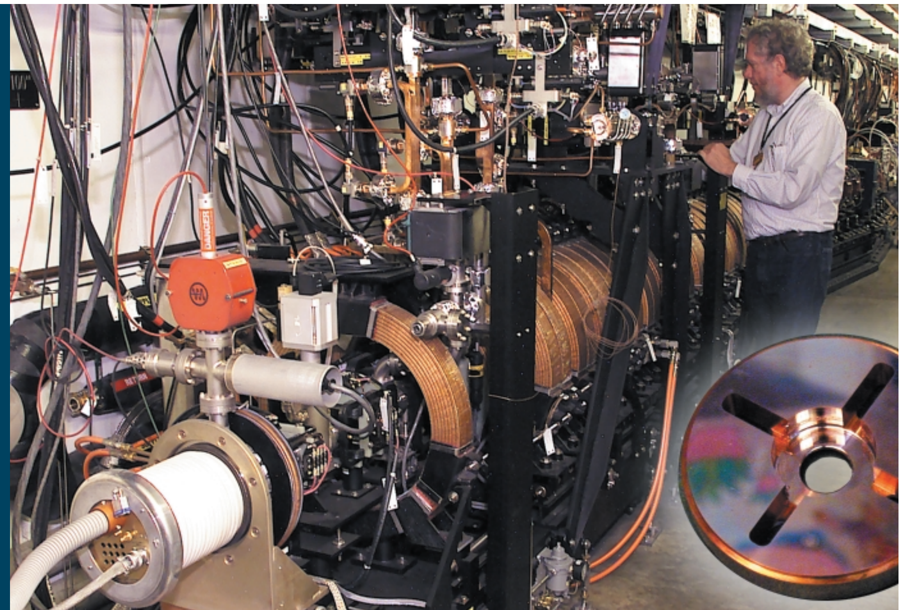
The pursuit of fundamental science and the advance of applied technology go hand in hand at Livermore. State-of-the-art technology is used to increase our understanding of science in areas pertinent to the Laboratory's major missions. Conversely, Livermore's scientific advances have important spin-off applications and help to achieve program goals.

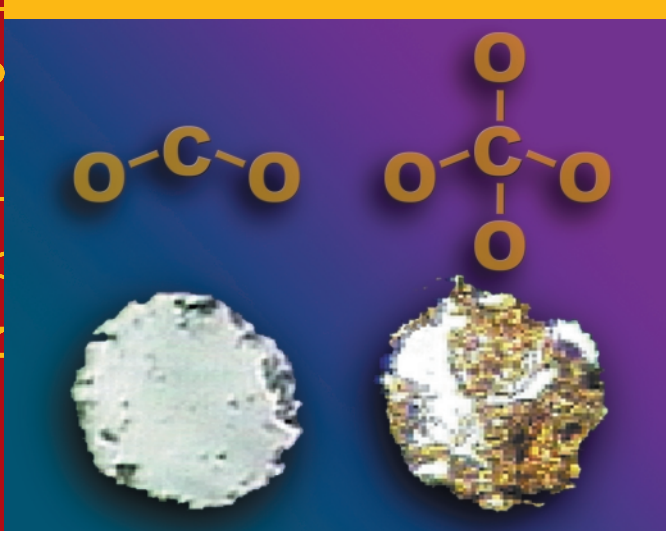


Pursuing Breakthroughs in Science and Technology

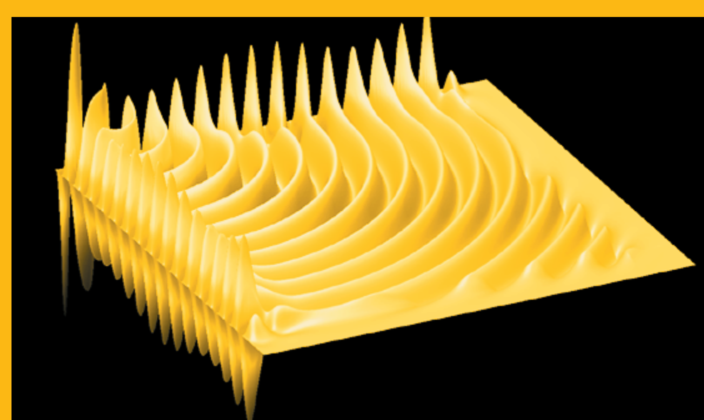
Understanding How Materials Age

Computer simulations combined with experiments are providing new insights about the aging of materials. Of particular interest to Laboratory researchers is the long-term effect of radiation on materials—for applications ranging from pressure vessels in nuclear reactors to radioactive waste containers to components of nuclear warheads. A team of Laboratory researchers reported in *Nature* new findings that connect radiation damage in crystalline metals, which occurs at ultrasmall scales (nanometers and picoseconds), to degradation over time of its mechanical properties. Because radiation damage to materials is a multiscale phenomena, the process must be modeled accordingly.

The team used atomistic and 3D microscale simulations of irradiated metals. The simulations showed that nanoscale defects accumulate and quickly grow into clusters. These clusters inhibit the movement of dislocations (misaligned planes of atoms) and make the material more brittle. Simulations also accurately predicted the formation of defect-free channels in irradiated metals through the



Researchers study the equation of state of materials at extreme conditions using Livermore's diamond anvil cell. They created two forms of solid carbon dioxide never before seen in the laboratory (CO_2-IV, left, and CO_2-V, right). CO_2-V has covalent bonds and shows nonlinear optical behavior, which may eventually lead to a new class of generating materials for high-power lasers.



Researchers from Livermore and Berkeley national laboratories and the University of California at Davis used supercomputers to obtain a complete solution to the ionization of a hydrogen atom by collision with an electron. The results were reported in *Science* and *Physics Today*. The computed radial wave function of the two electrons in the collision is shown above.

Livermore is contributing expertise in the design of the power modulators (left) and the precision engineering of copper cells for the accelerator structure (right) in the proposed Next Linear Collider.

annihilation of defects as dislocations move. These clear channels, which were observed in experiments, reduce material strength.

Next Linear Collider

The proposed Next Linear Collider (NLC) is designed to collide electrons and their antiparticles (positrons) after they have been accelerated to exceptionally high energy—about a trillion electron volts. The energy released will go into the creation of new particles. The experiments will help physicists answer some of the most fundamental questions about the nature of matter and the structure of space–time. The NLC is being developed through a collaboration of four DOE laboratories—Stanford Linear Accelerator Center (SLAC), Lawrence Livermore and Lawrence Berkeley national laboratories, and Fermi National Accelerator Laboratory.

Livermore's contributions include the development of power modulators for the NLC's linear accelerators. Based on solid-state technology, our new modulator for the NLC is designed to be affordable, efficient, reliable, and serviceable. Modulator cells were built and successfully tested, and in 2000, a complete modulator (consisting of 75 cells) was fabricated and delivered to SLAC. The NLC also will require between 5,000 and 10,000 structures to accelerate bunches of electrons and positrons. Each structure has about 200 precision copper cells, each slightly different. Livermore's role is to develop cost-efficient procedures for diamond-turning these cells to micrometer-level tolerances and to fabricate prototypes.

JanUSP to Explore New Plasma Regimes

Livermore's JanUSP has set the record as the world's brightest laser. The laser produces ultrashort pulses (less than a tenth of a trillionth of a second long) and has achieved an irradiance of two sextillion (2×10^{21}) watts per square centimeter. This level of brightness allows scientists to explore plasma conditions similar to those inside stars and detonating nuclear weapons, with pressure one trillion times that of Earth's atmosphere at sea level.

Scientists plan to heat small samples of material by using the enormous pressure of the laser light to ionize surface material and accelerate the ions into the sample. In less than a billionth of a second, the sample will turn into a superhot plasma (about 10 million degrees). For the experiments to succeed, the rise time of the laser pulse must be extremely fast with no prepulse. In 2000, researchers achieved the goal of reducing the prepulse energy from JanUSP to less than one ten-billionth that of the main pulse.

ISO 9002

The Laboratory's Engineering Manufacturing and Services Group is officially registered as compliant with the International Standards Organization ISO 9002—a worldwide benchmark for assuring high quality and customer satisfaction in production, installation, and service. ISO certification was awarded following an audit by Bureau Veritas Quality International, an independent agency that checked for compliance with ISO quality standards at all levels, including management policies, operating procedures, and work process. The group is believed to be the first within the DOE complex to receive this quality certification.

Materials simulations are closely coupled to laboratory experiments, including measurements of the transport properties of radiation damage defects in metals (left). An electron micrograph of molybdenum (top right) is used to establish initial conditions in a simulation of dislocation dynamics, one step in multiscale modeling. After compression, many dislocations run through the crystalline lattice (bottom right).